Am J Transl Res 2024;16(8):4174-4181
www.ajtr.org /ISSN:1943-8141/AJTR0158181

Original Article

Correlation analysis of BMI with ovulation effect and clinical pregnancy rate in patients with polycystic ovary syndrome

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Received May 30, 2024; Accepted July 24, 2024; Epub August 15, 2024; Published August 30, 2024

Abstract: Objectives: The study was designed to investigate the correlation between body mass index (BMI) along with both ovulation effect and clinical pregnancy rate in patients with polycystic ovary syndrome (PCOS), as well as to analyze the factors influencing the clinical pregnancy rate. Methods: In the retrospective study, data from 122 patients were collected. The patients were classified into three groups based on their pre-pregnancy BMI: normal weight, overweight group, and obese group. The analysis focused on examining the ovulation indicators, ovulation rates, and clinical pregnancy rates across different groups. Furthermore, both univariate and multivariate analyses were conducted to identify factors influencing the clinical pregnancy rate. Results: The obese group exhibited significantly higher fasting plasma glucose (FPG) levels compared to the overweight and normal-weight groups ($P<0.0001$); but no significant difference was found between the overweight and normal-weight groups ($P>0.05$). Both the obese and overweight groups had elevated levels of low-density lipoprotein cholesterol (LDL-C) compared to the normal-weight group ($P<0.0001$), with no significant difference between the obese and overweight groups ($P>0.05$). The obese group exhibited significantly lower levels of high-density lipoprotein cholesterol (HDL-C) compared to the normal-weight group ($P<0.05$); but no significant difference in HDL-C levels was observed between the overweight and normal-weight groups ($P>0.05$). Both the overweight group and obese group showed notably higher endometrial thickness and diameter of mature follicles than the normal weight group ($P<0.05$), as well as notably fewer mature follicles ($P<0.05$). Furthermore, the obese group demonstrated a significantly lower number of mature follicles compared to the overweight group ($P<0.05$). Conversely, the diameter of mature follicles was found to be significantly higher in the obese group than in the overweight group ($P<0.05$). The endometrial thickness showed a positive correlation with BMI ($r=0.657$, $P<0.001$), while the number of mature follicles exhibited a negative correlation with BMI ($r=-0.547$, $P<0.001$). Additionally, the diameter of mature follicles demonstrated a positive correlation with BMI ($r=0.681$, $P<0.001$). Relatively high BMI, advanced maternal age, and elevated FPG were identified as independent risk factors associated with low clinical pregnancy rate in patients with PCOS. Conclusions: Relatively high BMI, advanced maternal age, and elevated FPG are independent risk factors associated with a decreased likelihood of achieving clinical pregnancy in patients. Therefore, in clinical practice, assisting obese patients in weight reduction to maintain a BMI within the normal range of 18.5-23.9 kg/m^2 and lowering blood glucose levels can contribute to better pregnancy outcomes.

Keywords: BMI, polycystic ovary syndrome, ovulation effect, clinical pregnancy rate

Introduction

Polycystic ovary syndrome (PCOS) is a systemic disorder characterized by female reproductive endocrine dysfunction [1]. It is a prevalent condition with a high incidence rate and is associated with significant heterogeneity, as well as various short- and long-term complications. The complex nature of PCOS and its multifaceted treatment approaches can have a profound impact on the quality of life and long-term health of affected women in their reproductive years [2, 3]. It is estimated that PCOS affects approximately 5%-18% of women [4]. PCOS is a complex condition characterized by hyperandrogenism, chronic anovulation, infertility, and metabolic disorders [5].

Prior research has found that PCOS can trigger health problems related to the accumulation of

https://doi.org/10.62347/KYES1276

adipose tissue, such as obesity, insulin resistance, metabolic syndrome, and type 2 diabetes [6]. The influence of obesity on the reproductive system of women in their childbearing age continues to be a subject of active research. It has been found that approximately 40%-70% of women diagnosed with PCOS also experience obesity. This obesity can have detrimental effects on various reproductive processes, particularly during in vitro fertilization-embryo transfer (IVF-ET) treatment. Obesity in PCOS patients can lead to prolonged use of gonadotropins, lower fertilization rates, and ultimately contribute to adverse pregnancy outcomes [7, 8]. Obesity itself can exacerbate PCOS symptoms, such as ovulation disorders or hyperandrogenism, while also increasing the long-term risk of cardiovascular diseases [9-11].

In obese-type PCOS patients, the primary manifestation is abnormally elevated insulin secretion. Elevated insulin levels in PCOS patients indirectly contribute to increased free testosterone levels. On the other hand, non-obese PCOS patients typically present with elevated levels of luteinizing hormone (LH). Prolonged elevation of LH stimulates excessive androgen secretion by the follicular membrane cells [12, 13]. Relatively high levels of androgens may lower the pregnancy rate in patients [14, 15]. However, prior research has rarely explored the specific impact of body mass index (BMI) on the ovulatory response in PCOS patients.

Accordingly, this study aimed to understand the relationship between BMI and the ovulatory response in PCOS patients, as well as the specific factors that may affect the clinical pregnancy rate. This information is beneficial for the prevention and improvement of infertility outcomes in PCOS patients.

Materials and methods

Ethnical statement

The research protocol was approved by the Medical Ethics Committee of the Changde Maternal and Child Health Care Hospital (Ethnical approval number: TZ90356).

Sample collection and grouping

This retrospective study analzyed the clinical data of 172 PCOS patients who visited the outpatient clinic of Changde Maternal and Child Health Care Hospital between January 2022 and February 2023. Diagnostic criteria of PCOS: (1) presence of menstrual abnormalities or irregular uterine bleeding; (2) presence of clinical manifestations such as hirsutism, acne, and/or laboratory evidence of hyperandrogenism; (3) transvaginal ultrasound examination performed on the 2nd to 3rd day of the menstrual cycle, showing the presence of ≥12 follicles with a diameter of 2-9 mm in a single ovary and/or ovarian volume ≥10 ml. Patient who met the conditions (1) and fulfil the conditions (2) and/or conditions (3) can be diagnosed as having PCOS after excluding other diseases that may cause hyperandrogenism and ovulation abnormalities [16].

Cases were excluded if they met the following criteria: (1) Chromosomal abnormalities regardless of gender; (2) Presence of endocrine disorders such as impaired glucose tolerance, diabetes, thyroid dysfunction, severe chronic diseases, diseases that restrict pregnancy, or malignant tumors; (3) Presence of abnormalities in uterine morphology and development, endometriosis (stage III-IV), uterine fibroids (≥5 cm), excessively thin endometrium (≤7 mm), or endometrial lesions; (4) Presence of tubal fluid accumulation, pelvic abdominal tuberculosis, or a history of complex pelvic abdominal surgery; (5) Use of donated oocytes as the source; (6) Missing data.

A screening process based on the inclusion and exclusion criteria resulted in a final sample of 122 cases. Patients with normal weight (18.5 kg/m^2≤BMI<24.0 kg/m^2) before pregnancy were classified into the normal weight group (n=52); overweight patients (24.0 kg/m^2≤BMI<28.0 kg/m^2) before pregnancy were classified into the overweight group (n=40) and patients with obesity (BMI≥28.0 kg/m^2) before pregnancy were classified into the obese group (n=30).

The data collection process for this study is illustrated in **Figure 1**.

Data collection

Baseline demographics and clinical characteristics of cases were collected from the electronic database, including BMI (body mass index), maternal age, weight, primipara, marriage status, abortion history, infertility dura-

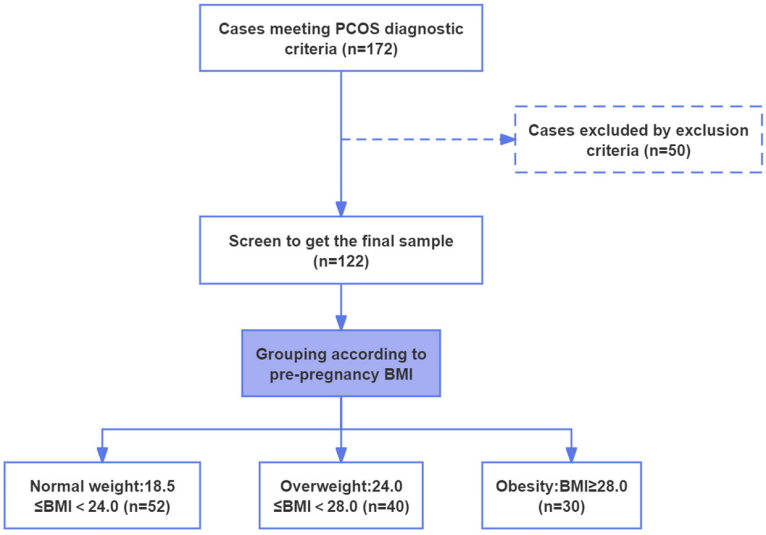

Figure 1. Research flow chart.

Table 1. Characteristics of study participants (n=122)

Characteristic	
BMI (kg/m^2)	24.90±3.61
Maternal age (years)	29.59±3.39
Normal weight (n)	52 (40.98)
Overweight (n)	40 (31.15)
Obese (n)	30 (27.87)
Primipara (n)	87 (71.31)
Married (n)	110 (90.16)
Abortion history (n)	59 (48.36)
Infertility duration (years)	5.08±0.45
SBP (mmHg)	105.84±10.99
DBP (mmHg)	70.41±7.66
FPG (mg/dl)	83.78±8.89
LDL-C (mg/dl)	99.24±11.58
HDL-C (mg/dl)	55.72±8.23

Notes: BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FPG: Fasting plasma glucose; LDL-C: Low density lipoprotein cholesterol; HDL-C: High density lipoprotein cholesterol.

tion, SBP (systolic blood pressure), DBP (diastolic blood pressure), FPG (fasting plasma glucose), LDL-C (low density lipoprotein cholesterol), HDL-C (high density lipoprotein cholesterol), ovulation, and follicle maturity. Blood pressure was measured using an Omron Digital Blood Pressure Monitor (HEM_907XL; OMRON IntelliSense, Beijing, China). LDL-C and HDL-C were measured using the AU2700 fully automated biochemical analyzer (Beckman Coulter, USA).

Vaginal ultrasound (Shanghai Sunbright Industrial Co., Ltd.; model: SUN-800D) was used to assess ovulation and follicle maturity in the two groups. The indicators encompassed endometrial thickness, number of mature follicles, and diameter of mature follicles. Clinical pregnancy rate and ovulation rate were confirmed through ultrasound examination of the gestational sac.

Statistical analysis

The collected data were entered into Excel (Microsoft® Excel® 2010). SPSS 25.0 was used for data analysis. Normality tests were performed on the measurement data. Normally distributed data were presented as mean ± standard deviation. Measurement data was compared between the two groups using independent sample t-tests, and compared among groups using the Analysis of Variance. Counting data were presented as frequencies and percentages and analyzed using the chi-square test or Fisher's exact test. Pearson correlation analysis was conducted to explore the relationship between BMI and ovulation indicators. Multivariable logistic regression models were used for multivariate analysis to calculate odds ratios (OR) and 95% confidence intervals (CI). $P<0.05$ was considered with notable difference.

Results

Clinical baseline data of patients

A total of 122 patients were evaluated, with a mean age of (29.59±3.39) years. Among them, 52 cases had a normal weight; 40 cases were overweight, and 30 cases were obese. The characteristics of the study participants are presented in **Table 1**.

Comparison of glucose- and lipid-related indices among the three groups of patients

An analysis was conducted to compare the levels of fasting plasma glucose (FPG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) among the three groups. The obese group had significantly

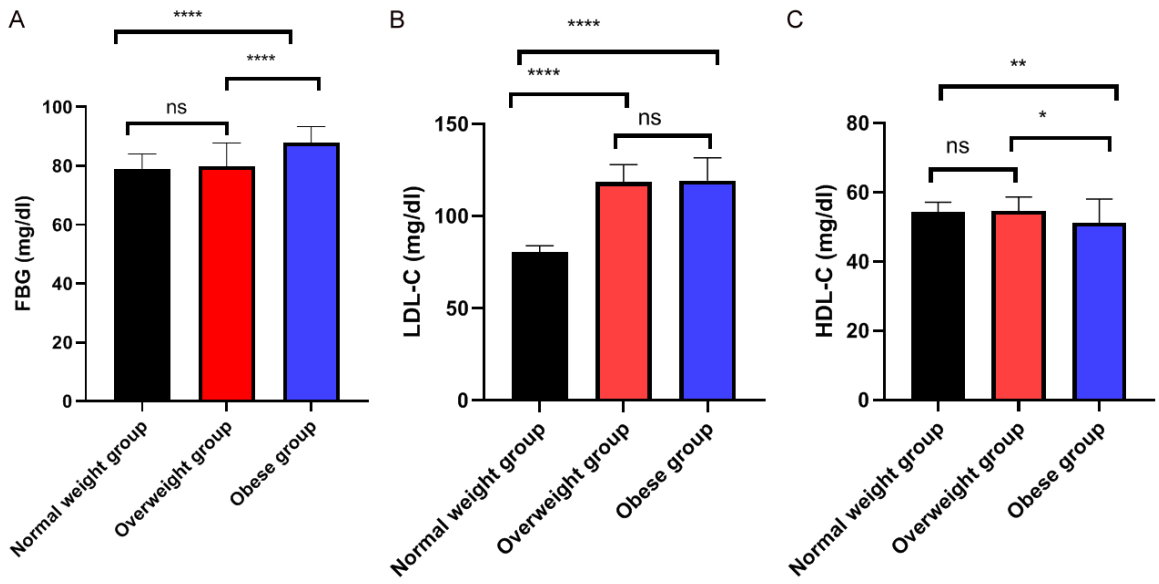

Figure 2. Comparison of FPG, LDL-C, and HDL-C among patients in different BMI categories. A: Comparison of FPG among patients in different BMI categories. B: Comparison of LDL-C among patients in different BMI categories. C: Comparison of HDL-C among patients in different BMI categories. Notes: nsP>0.05; *P<0.05; **P<0.01; ****P<0.0001. FPG: Fasting plasma glucose; LDL-C: Low-density lipoprotein cholesterol; HDL-C: High-density lipoprotein cholesterol.

Table 2. Comparison of ovulation-related indicators among patients in different BMI categories

	Normal weight group (n=52)	Overweight group (n=40)	Obese group (n=30)
Endometrium thickness (mm)	7.32±1.27	8.79±1.43[a]	9.26±1.08[a]
Number of mature follicles (number)	3.60±0.42	3.15±0.83[a]	2.43±0.73[a,b]
Mature follicle diameter (mm)	19.18±1.06	20.12±0.96[a]	21.00±0.95[a,b]

Notes: [a]P<0.05 *vs.* the normal weight group; [b]P<0.05 *vs.* the overweight group.

higher FPG levels compared to the overweight and normal-weight groups (P<0.0001). However, there was no significant difference between the overweight and normal-weight groups in FPG levels (P>0.05). Both the obese and overweight groups demonstrated significantly elevated levels of LDL-C compared to the normal-weight group (P<0.0001). However, there was no significant difference in LDL-C levels between the obese and overweight groups (P>0.05). The obese group exhibited a notably decrease in HDL-C levels compared to the normal-weight group (P<0.05), while there was no statistically significant difference between the overweight and normal-weight groups (P>0.05). Refer to **Figure 2** for more details.

Comparison of ovulation indicators among the three groups of patients

Table 2 presents the differences in ovulation indicators among patients in different BMI categories. The endometrial thickness and diameter of mature follicles were notably higher in the overweight and obese groups compared to the normal weight group (P<0.05). In contrast, the number of mature follicles was notably fewer in the overweight and obese groups compared to the normal weight group (P<0.05). Additionally, the obese group had significantly fewer mature follicles compared to the overweight group (P<0.05), while the diameter of mature follicles was significantly higher in the obese group compared to the overweight group (P<0.05). **Figure 3** displays the correlation between BMI and various ovulation indicators in the pregnant women. The endometrial thickness showed a positive correlation with BMI (r=0.657, P<0.001), while the number of mature follicles exhibited a negative correlation with BMI (r=-0.547, P<0.001). Furthermore, there was a significant positive correlation between BMI and the diameter of mature follicles (r=0.681, P<0.001).

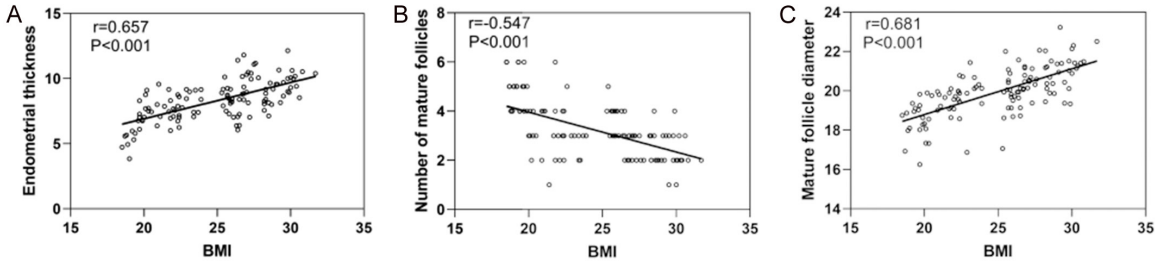

Figure 3. Correlation between BMI and various ovulation indicators in pregnant women. A: There was a positive correlation between endometrial thickness and BMI (r=0.657, P<0.001). B: The number of mature follicles was negatively correlated with BMI (r=-0.547, P<0.001). C: The diameter of mature follicles was positively correlated with BMI (r=0.681, P<0.001). Note: BMI: Body mass index.

Table 3. Pregnancy outcomes in different BMI categories [n (%)]

	Normal weight group (n=52)	Overweight group (n=40)	Obese group (n=30)
Ovulation rate	36 (69.23)	23 (57.50)	13 (43.33)[a]
Clinical pregnancy rate	29 (55.77)	13 (32.50)[a]	8 (26.67)[a]

Note: [a]P<0.05 *vs.* normal weight group.

Table 4. Results of univariate regression analysis

	Clinical pregnancy (n=50)	Non-clinical pregnancy (n=72)	P
BMI (kg/m^2)	22.88±3.63	26.31±2.87	<0.001
Maternal age (years)	27.32±2.72	31.17±2.88	<0.001
Primipara	36 (72.00)	51 (70.83)	0.889
Married	43 (86.00)	67 (93.06)	0.206
Abortion history	17 (34.00)	42 (58.33)	0.009
Infertility duration (years)	4.88±0.44	5.10±0.39	0.003
SBP (mmHg)	106.01±11.49	105.73±10.71	0.889
DPB (mmHg)	71.20±7.42	69.86±7.82	0.343
FPG (mg/dl)	78.01±6.66	87.79±8.01	<0.001
LDL-C (mg/dl)	98.89±12.35	99.46±11.10	0.779
HDL-C (mg/dl)	56.67±8.30	55.06±8.17	0.289

Notes: BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FPG: Fasting plasma glucose; LDL-C: Low density lipoprotein cholesterol; HDL-C: High density lipoprotein cholesterol.

Comparison of pregnancy outcomes among patients in different BMI categories

Table 3 displays the pregnancy outcomes among patients in different BMI categories. No notable difference was observed in ovulation rates between the normal weight group and the overweight group (χ^2=1.353; P=0.245). Similarly, no notable difference in ovulation rates was found between the overweight group and the obese group (χ^2=1.377; P=0.241). However, the obese group had a significantly lower ovulation rate compared to the normal weight group (χ^2=5.306; P=0.021). The clinical pregnancy rates were significantly lower in both the overweight and obese groups compared to the normal weight group (χ^2=4.934; P=0.026; χ^2=6.507; P=0.011). No notable difference was found in clinical pregnancy rates between the overweight and obese groups (χ^2=0.278; P=0.598).

Univariate regression analysis

The patients were divided into two groups: a clinical pregnancy group (n=50) and a non-clinical pregnancy group (n=72). A univariate analysis was conducted to examine the variables. The results revealed that BMI, maternal age, history of miscarriage, duration of infertility, and FPG were potential factors influencing pregnancy outcomes (all P<0.05, **Table 4**).

Multivariate regression analysis

Multivariate analysis of the indicators with significant differences in the univariate analysis indicated that relatively high BMI, advanced maternal age, and relatively high FPG were independent risk factors for failure to achieve clinical pregnancy (**Table 5**).

Discussion

This study reveals that BMI is positively correlated with endometrial thickness and the diam-

Table 5. Results of multivariate regression analysis

	Clinical pregnancy (n=50)	Non-clinical pregnancy (n=72)	P	OR	95% CI
BMI (kg/m^2)	22.88±3.63	26.31±2.87	0.004	1.293	1.084-1.542
Maternal age (years)	27.32±2.72	31.17±2.88	<0.001	1.691	1.311-2.182
Abortion history	17 (34.00)	42 (58.33)	0.622	1.349	0.411-4.435
Infertility duration (years)	4.88±0.44	5.10±0.39	0.113	2.536	0.802-8.022
FPG (mg/dl)	78.01±6.66	87.79±8.01	<0.001	1.208	1.093-1.335

Notes: BMI: Body mass index; FPG: Fasting plasma glucose.

eter of mature follicles. Conversely, BMI is negatively associated with the number of mature follicles. Notably, patients classified as being obese based on their BMI demonstrated lower rates of ovulation and clinical pregnancy compared to individuals with normal weight or who are overweight. Further multivariate analysis revealed that relatively high BMI, advanced maternal age, and relatively high fasting plasma glucose were independent risk factors for failure to achieve clinical pregnancy.

Prior research has found that PCOS patients are more prone to insulin resistance, and increasing evidence suggests that insulin resistance is an important component of the pathological mechanism of PCOS [17]. Obesity, especially excessive accumulation of visceral fat, is closely associated with insulin resistance in patients with PCOS [18]. Obesity and insulin resistance mutually reinforce each other, affecting hormone levels, egg maturation, embryo quality, endometrial receptivity, and increasing the risk of infertility, pregnancy complications, and poor outcomes in assisted reproduction for PCOS patients. Research suggests that obesity may impact the feedback regulation of the hypothalamic-pituitary-gonadal axis, exacerbating hormonal imbalances in the reproductive system of PCOS patients. Studies have pointed out that PCOS patients face a higher risk of miscarriage compared to normal individuals, with the increased risk primarily occurring between weeks 12 and 28 of pregnancy [19, 20]. Thus, it is crucial to prioritize the assessment of obesity in patients with PCOS and enhance the detection rates of both overall and central obesity. By doing so, we can effectively address this important factor and potentially improve reproductive outcomes in individuals with PCOS. In this study, the obese group had significantly higher FPG levels compared to the overweight and normal-weight groups. Both the obese and overweight groups had elevated levels of LDL-C compared to the normal-weight group. The obese group had lower levels of HDL-C compared to the normal-weight group. These results highlight that obesity is associated with adverse metabolic markers (such as high FPG, elevated LDL-C, and low HDL-C levels) in women. In addition, no notable difference was found in ovulation rates between the normal weight and overweight groups. Similarly, no notable difference was observed in ovulation rates between the overweight and obese groups. However, the obese group had a significantly lower ovulation rate compared to the normal weight group. The clinical pregnancy rates were significantly lower in both the overweight and obese groups compared to the normal weight group. The overweight and obese groups did not differ notably in clinical pregnancy rates.

In PCOS patients, it is common to observe the presence of multiple immature follicles instead of mature follicles in the ovaries. This condition leads to the formation of numerous small follicles, which can hinder the process of normal ovulation. The higher the number of mature follicles and the more appropriate their diameter, the higher the ovulation rate [21, 22]. In individuals with PCOS, there is often an imbalance of estrogen, resulting in an excessive thickening of the endometrium. This imbalance occurs due to insufficient levels of progesterone, which allows estrogen to continue exerting its effects on the endometrium, causing it to become abnormally thick. This thickened endometrium can interfere with regular ovulation or reduce the pregnancy chance [23-25]. This study also demonstrated a positive correlation between BMI and endometrial thickness as well as the diameter of mature follicles, and a negative correlation between BMI and the number of mature follicles. Patients classified as being

obese also had significantly lower ovulation rates and clinical pregnancy rates compared to those with those who are normal weight and overweight. Aldarazi et al. [26] found that endometrial thickness has a positive correlation with endometrial hyperplasia in subfertile women with polycystic ovary syndrome, which supports the results of this study. The underlying mechanisms behind the correlation can be attributed to the following: In the case of patients with high BMI and endometrial thickness, it is believed that increased adiposity and higher levels of circulating estrogen in obese individuals may contribute to greater endometrial proliferation and thickening.

The findings of this study, as determined through logistic regression analysis, indicate that relatively high BMI, advanced maternal age, and elevated FPG levels are independent risk factors for failure in clinical pregnancy in PCOS patients. Obesity exacerbates insulin resistance and hyperinsulinemia, leading to increased fat deposition. Obesity increases the sensitivity of follicular cells to luteinizing hormone, upregulates ovarian androgen production, and worsens the endocrine imbalance in PCOS, potentially increasing the risk of miscarriage [27-29]. Higher FPG level interferes with the secretion of hormones such as insulin, leading to imbalances in other hormones required for maintaining pregnancy and fetal development [30]. Persistent elevation of blood glucose levels can lead to detrimental effects on blood vessels, disrupt the provision of essential nutrients to the developing fetus, compromise the functioning of the placenta, and ultimately impact the outcomes of pregnancy [31].

The strengths of this study include: (1) The correlations between BMI and ovulation indicators of PCOS patients were observed. (2) The independent factors affecting the clinical pregnancy of PCOS patients were analyzed. However, given the limitations of this study, our research findings should be interpreted with caution. Due to the retrospective nature of the study, some important factors such as hormone levels and cervical length were not available for certain patients during pregnancy. Furthermore, the results obtained from this study may not be applicable to all PCOS patients and individuals of other ethnicities. The conclusions drawn from this study should be further validated through large-scale and multi-center prospective studies.

Conclusion

Our study data indicates that increasing BMI is associated with decreased ovulation rate and clinical pregnancy rate in PCOS patients. Relatively high BMI, advanced maternal age, and elevated fasting plasma glucose are independent risk factors leading to failure in clinical pregnancy in PCOS patients. Therefore, in clinical practice, assisting obese patients in weight reduction to maintain a BMI within the normal range (18.5-23.9 kg/m^2) and lowering blood glucose levels can contribute to better pregnancy outcomes.

Disclosure of conflict of interest

None.

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